bottom side of polymer **12** around the edges of an active area corresponding to the surface shape of electrode **16** (and to a lesser extent, electrode **14**). The polymer surface features **17** generally result from the fact that while the actuated polymer **12** increases in surface area over an active area proximate to electrodes **14** and **16**, the polymer often (depending on design) decreases in area over the inactive regions of the polymer. The bulging polymer surface features **17** then include displaced polymer material, typically located at the edges of an electrode for an active area. Surface region **21** for the top surface of transducer **10** in this case then includes the planar area of electrode **14** and polymer surface features **17***a-b*.

[0044] In addition to the elevated polymer surface features **17**, polymer **12** and one or both electrodes **14** and **16** of transducer **10** are configured to produce a lowered electrode portion **27** that rests below the undeflected thickness **22** after the deflection due to actuation. In this case, all of electrode **14** on the top surface is depressed below the undeflected thickness **22** after deflection. The depressed electrode portion **27** also acts as an electrode surface feature **19***a* created by actuation and deflection of polymer **12** and thinning of polymer **12** around electrodes **14** and **16**. For example, if electrode **14** is shaped as a circle, then the electrode surface feature **19***a* will be a depressed circle when viewed from the top, while polymer surface feature **17** will comprise an elevated 'O' or ring about the depressed circle. As will be described in greater detail below, electrodes **14** and **16** can be patterned or designed to produce customized polymer surface features **17** and electrode surface features **19**, such as letters (e.g., a, n, y, l, e, t, r) or more complex patterns and shapes.

[0045] Bottom electrode **16** similarly expands in the plane and thins to create an electrode surface feature **19***b* on the bottom side of transducer **10**. Electrode surface feature **19***b* rests below the undeflected thickness **22** for the bottom side of transducer **10**. Elastic resistance in polymer **12** to expansion of polymer **12** in an active area between electrodes **14** and **16** also creates polymer surface features **17***c-d* on the bottom side of transducer **10**.

[0046] While out-of-plane surface features **17** are shown relatively local to the active area, the out-of-plane is not always localized as shown. In some cases, if the polymer is pre-strained, then the surface features **17***a-b* are stretched or smoothed out over the inactive polymer material. The magnitude of out-of-plane deformation may vary with the exact geometry, pre-strain, etc. However, regardless of whether it is described as a local bulge or distributed, the inactive regions generally become thicker in cross section.

[0047] In general, the transducer **10** (polymer **12** and electrodes) continues to deflect until mechanical forces balance the electrostatic forces driving the deflection. More specifically, polymer **12** between electrodes **14** and **16** and in the active area continues to expand and thin, while polymer surface features **17** continue to elevate from the surfaces of polymer **12** and electrode surface feature **19** continue to form by the thinning of polymer **12**, until mechanical forces balance the electrostatic forces driving the deflection. The mechanical forces include elastic restoring forces of the polymer **12** material inside and outside the active area, the compliance of electrodes **14** and **16**, and any external resistance provided by a device and/or load coupled to the transducer portion **10**, etc. The deflection of the transducer portion **10** as a result of the applied voltage may also depend on a number of other factors such as the polymer **12** dielectric constant and the size of polymer **12**.

[0048] **FIG. 1E** illustrates a transducer **60** comprising a rigid layer **62** in accordance with one embodiment of the present invention. Transducer **60** comprises rigid layer **62**, electroactive polymer **64**, top surface electrode **66**, bottom surface electrode **68**, polymer surface features **63** and electrode surface features **65**.

[0049] Rigid layer **62** attaches to a bottom surface of polymer **64** and prevents the bottom surface of polymer **64** from deflecting. As a result, only the top surface of polymer **64** includes polymer surface features **63** and electrode surface feature **65**.

[0050] Rigid layer **62** may comprise a rigid structure such as a stiff metal or non-metal plate, for example. In one embodiment, rigid layer **62** comprises a non-compliant electrode material such as a suitably stiff metal, which then doubly acts as an electrode for the surface it attaches to and a rigid layer **62**. The rigid layer **62** electrode may be any type of conductive material. For instance, the rigid layer **62** electrode may be a metal, such as copper, aluminum, gold, silver, etc. In another specific embodiment, the rigid layer **62** electrode may comprise a conductive ceramic-based composite material.

[0051] Polymer **64** may be bonded to rigid layer **62** using a bonding agent. Partially bonding between polymer **64** and the structure, i.e. the area of the bonding agent is less than the area of contact between polymer **64** and rigid layer **62**, permits customized deflections of polymer **64**. For example, for a rectangular polymer **64** and rigid layer **62**, polymer **64** may be bonded to rigid layer **62** along two edges of the rectangle. In this case, polymer **64** expands relative to rigid layer **62** in the un-bonded direction. During expansion of polymer **64**, a lubricant may be disposed between rigid layer **62** and polymer **64** to reduce friction between the two surfaces. An optional passive layer may also be disposed between rigid layer **62** and polymer **64**. The passive layer is selected so that it deflects as polymer **64** deflects. This specific embodiment allows polymer **64** to expand more as compared to when it is directly bonded to rigid layer **62**.

[0052] Generally, polymers that are suitable for use with transducers of this invention include any substantially insulating polymer or rubber (or combination thereof) that deforms in response to an electrostatic force or whose deformation results in a change in electric field. Preferably, the polymer's deformation is reversible over a wide range of strains. Many elastomeric polymers may serve this purpose. In designing or choosing an appropriate polymer, one should consider the optimal material, physical, and chemical properties. Such properties can be tailored by judicious selection of monomer (including any side chains), additives, degree of cross-linking, crystallinity, molecular weight, etc.

[0053] Polymer **12** may assume many different physical and chemical states. For example, the polymer may be used with or without additives such as plasticizers. And they may be monolithic polymeric sheets or combinations of polymers such as laminates or patchworks. Further, the polymers may exist in a single phase or multiple phases. One example of a multiphase material is a polymeric matrix having inorganic filler particles admixed therewith.